Dynamic Performance Simulation and Test of a Conveyor

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ABSTRACT

This paper puts forward the application of AMESim to a belt conveyor model. Based on discrete element method, a conveyor dynamic model is studied. A belt, idler and material are divided into finite units. Each unit is represented by a spring, damper and mass. Take-up model considers its dual friction when it moves up and down. The model of function of input and linear signal source is selected to build a model of a drive system and brake system. The performance simulation on belt velocity of a conveyor during starting and stopping process is carried out. A velocity test on spot for the whole operation is conducted. The simulation is compared to a velocity test on spot. The comparison shows that both are in good agreement. Two cases are studied for different load conditions, different load take-ups and different conveyor stop type. The AMESim model of a conveyor and its method are right.

Keywords: Conveyor AMESim Model, Simulation, Test

1. INTRODUCTION

For a traditionally designed belt conveyor, its operational performance is difficult to be exactly determined before its setup. Also the parameter or scheme should be redesigned in order to satisfy the design requirements if its dynamic behavior is not reasonable. And a quick and exact modeling method is key to study conveyor performance for engineers.

Conveyor dynamic simulation has several main applications: dynamic performance analysis, prediction and modification. Many authors studied them with simulation [1-8]. For example, G.Lodewijks studied the stopping behavior of a decline conveyor and mentioned a method called dynamic tuning for the brake torque and flywheel [2]. And A.Harrison simulated the effect of reducing dynamic loads in belts powered by three wound rotor motors [7]. However, it seems that the conveyor design example by the help of dynamic performance prediction and modification is limited in number. Therefore, the engineering application in the conveyor dynamic simulation should be enhanced.

On the other hand, modeling methods and business software become more and easier with technology developed. Here in this paper a quick and exact modeling software, AMESim, is introduced [9]. AMESim is designed to develop and analyze multi-disciplinary system models. It is the ideal version for users who need to share models with other departments or with outside partners.

Via the easy and interactive graphical interface, AMESim users can build complex multi-domain system models in minutes by simply combining validated components from various libraries covering different physical domains. The result is a straightforward system model representation, which is easy to understand and investigate. Users create models by connecting physics-based building blocks. This innovative concept avoids cumbersome numerical model creation and code writing. Users are plunged directly into the critical aspects of design like analysis and optimization.

Based on the most advanced numerical techniques, the AMESim solver supports ordinary differential equation (ODE) and differential algebraic equations (DAE). The solver automatically and dynamically selects the best-adapted calculation method from 17 algorithms, depending on the system dynamics.

This paper predicts dynamics performance of a belt conveyor based on AMESim. And by a comparison to test parameters, this paper explains the conveyor AMESim model is in good agreement to the test.

2. CONVEYOR MODEL BASED ON AMESIM

A conveyor is a loop machine which can be divided into units from the view of finite element method. Belts, material, idlers, drive systems, brake systems and a take-up can find their position in each unit.

For belt, idler and material unit, each can be described using a spring, damper and mass. Thus, the force acting on ith unit of spring and damper

$$\boldsymbol{F_i} = K_i(x_{i2}-x_{i1})+C_i\left(\dot{x}_{i2}-\dot{x}_{i1}\right) \tag{1}$$

the force acting on *i* th unit of mass

$$\boldsymbol{F_i} = M_i\ddot{x}_{i1}+F_f \pm M_i g\sin\alpha_i \tag{2}$$

Where K_i, C_i are spring rate and damper rating of each unit, $x_{i2}, x_{i1}, \dot{x}_{i2}, \dot{x}_{i1}$ are displacement and displacement rate at both ends of spring and damper, $M_i, \ddot{x}_{i1}$ are mass and acceleration of each unit, α_i is conveyor angle, and $\boldsymbol{F_f}$ is friction force,

$$\boldsymbol{F_f} = \left(f_1+\left(f_2-f_1\right)e^{\frac{|\dot{x}_{i1}|}{3v_0}}\right)\times sign(\dot{x}_{i1}) \tag{3}$$

Where f_1 is coulomb friction force, f_2 is stiction force, v_0 is velocity threshold， and $sign(\dot{x}_{i1})$ is sign function.

Thus the model of belt, idler and material unit is shown in fig.1

Fig.1 Model of belt, idler and material unit

As for the models for drive and brake systems, the operation rotation speed or torque of motors and brakes can be described using curves. Fig.2 shows the AMESim models for drive and brake systems.

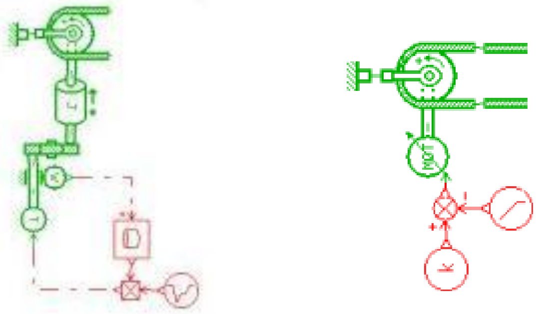

Fig.2 Models for drive system and brake system

Fig.3 illustrates a typical take-up system model based on AMESim. For a gravity take-up, the dual friction is considered when it moves up and down. But for a fixed take-up, no dual friction exists.

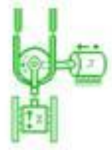

Fig.3 Take-up system model

A typical conveyor AMESim Model is shown in Fig.4. In its sketch mode one drive system and gravity take-up is mounted on the head of conveyor. Each unit is chosen and fit together; AMESim will automatically build conveyor system equation and calculate it according to initial values. The model of linear mass, spring-damper, drive and return sheave, reducer and rotary load may be found in Mechanical warehouse of AMESim. They consist of the mechanical part of conveyor

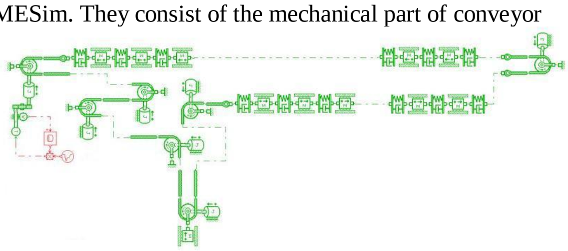

Fig.4 Conveyor AMESim Model

model. In Signal warehouse of AMESim, the model of function of input and linear signal source is selected to build a model of drive systems or brake system.

3. SIMULATION, TEST AND COMPARISONG

This section predicts belt performance in the process of conveyor start-up and stop.

The basic data of a belt conveyor studied is as following. It is 108.54 meter in length with a lift 3 m. The belt is canvas with the width of 800 mm and layers of five. The conveyor velocity is 2 m/s. It transports material 300t/h in full load condition. Idler spacing is 1 m on the carry strand and 1.2 m on the return strand. One motor is built at the head of conveyor with the power of 30 kW and rotation speed of 1470 rpm. The rotation ratio of a reducer is 31.5. And the diameter of drive pulley is 800 mm. The take-up is mounted near the drive pulley.

The simulation and test is carried out in the case of zero-load condition. And the start process of the conveyor employs the direct start of the motor. The stop process of the conveyor exists when no power is on the motor and no brake torque on the drive drum. So the belt velocity varies during the process of start and stop in fig.5 and fig.6 based on a conveyor AMESim model. From fig.5 and fig.6, the start process lasts around 3s during which belt velocity increases from zero to 2 m/s, and the stop process is about 4.3s during which belt velocity decreases from 2 m/s to zero.

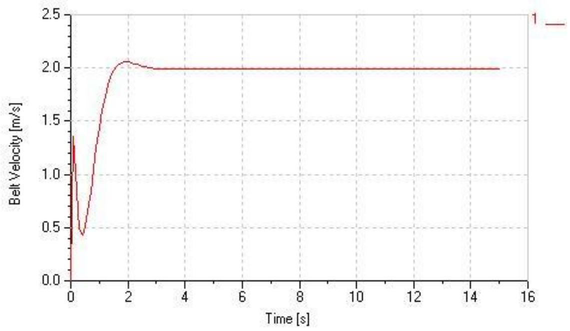

Fig.5 Belt velocity simulated in start process

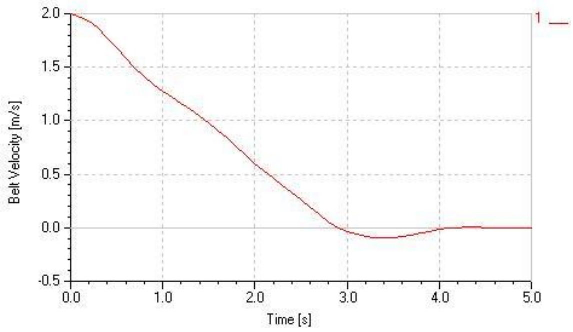

Fig.6 Belt velocity simulated in stop process

Fig.7 is the belt velocity test equipment. It uses a rubber wheel and encoder. Fig.8 shows the tested belt velocity history which includes start, normal operation and stop processes. From the test results, the start and stop time are 3.2s and 4s, respectively. Tab.1 finds a small time difference between simulation and test. Also from fig.7 and fig.8, a small velocity rebound is different, with the previous velocity negative and the latter velocity positive. After all, a good agreement reaches comparing fig.5, fig.6 and fig.8.

Fig.7 Test equipment

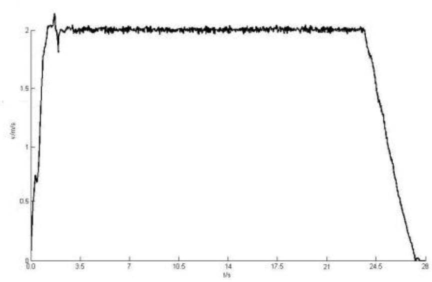

Fig.8 Tested belt velocity of the whole process

Tab.1 comparison of start and stop time simulated and tested

Operation condition	simulation	test
Start time (s)	3	3.2
Stop time (s)	4.05	4

In order to further study conveyor AMESim model, another case in different conditions is introduced.

A long belt conveyor is studied. Its basic data is as following. It is 7600 meter in length with a lift –175 m. The average inclined angle is about -1.3°. The belt specification is ST-2000, with a belt width of 1400 mm and mass per unit length of 54 kg/m. The conveyor velocity is 4 m/s. It transports material 2500t/h in full load condition. Idler spacing is 1.2 m on the carry strand and 3 m on the return strand. Idler diameter is 159 mm. The total power of three motors, built at the head of conveyor, is 800×3 kW. The rotation ratio of reducer is 19.25. There are two drive pulleys mounted on the head, the first one driven by two motors and the second one by one motor. The diameter of drive pulley is 1 m. The gravity take-up is mounted near the second drive pulley. The mass of gravity is 42800 kg.

This paper simulates the above conveyor in fully loaded below.

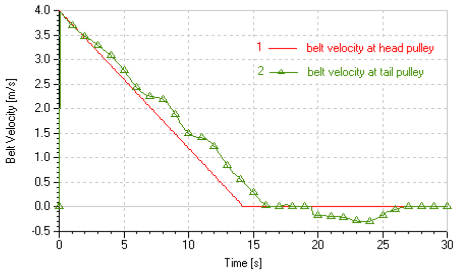

Fig.9 Belt velocity in braking stop process

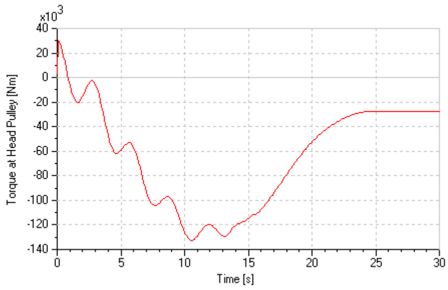

Fig.10 Braking torque in braking stop process

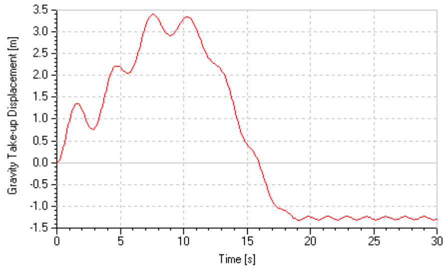

Fig.11 Gravity take-up displacement in braking stop process

1）Braking stop process

Supposed that the velocity of upper belt at drive pulley decreases in liner rule and the stop process lasts 14s in curve 1 in fig.9, then the velocity of upper belt at tail pulley changes as shown in curve 2 in fig.9 and the stop process lasts 16s. But during the period 19th s and 27th s, the velocity becomes negative, which shows the influence of belt elastic wave.

In fig.10, the braking torque increases step by step and climbs to the maximum value around 130kNm in 0—14th s. In 14th —25th s, the braking torque decreases and maintains the value 30kNm at last.

At the same time, the gravity take-up moves down (positive in figure) at first and then moves up (negative in figure) in fig.11. The maximum down displacement is about 3.5m. After 12th s, the gravity take-up moves up and stops at the position 1.3 m at last.

4. CONCLUSIONS

This paper illustrates how the new software AMESim is used to build and simulate conveyor system performance before its setup. By comparing the simulation with the test of belt velocity, a good agreement is reached. The case studies are for different load conditions, different load take-ups and different conveyor stop method. It shows AMESim is a quick and accurate method to simulate conveyor performance.

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